



"What happened to us this year, however, can only be described as a catastrophe of Biblical proportions. We in Louisiana know hurricanes and hurricanes know us. We would not be here today if the levees had not failed."

Kathleen Babineaux Blanco
Governor, State of Louisiana
Select Committee Hearing, December 14, 2005

Summary

The levees protecting New Orleans were not built to survive the most severe hurricanes. It was a well-known and repeatedly documented fact that a severe hurricane could lead to overtopping or breaching of the levees and flooding of the metropolitan area. In fact, for years the U.S. Army Corps of Engineers (USACE) has had a written plan for unwatering (i.e., draining) New Orleans in such a contingency. This well-known threat was the motivation for FEMA to sponsor the “Hurricane Pam” exercise. The potential for Katrina to be “the Big One” and breach the levees was also the key reason for the National Weather Service, Governor of Louisiana, and Mayor of New Orleans to issue such dire warnings.

Once construction of the levees was completed by USACE, the responsibilities for operating and maintaining the levees were split among many local organizations, which is the standard cooperation agreement for carrying out flood control projects nationwide. The costs of constructing these projects are shared, with operation and maintenance being a 100 percent local responsibility. These include levee boards in each parish, as well as separate water and sewer boards. The number of organizations involved, and disagreements among them, makes accountability diffuse and creates potential gaps and weaknesses in parts of the flood protection system. In one case, improvements to levee strength which may have mitigated or prevented some of the critical breaches that flooded downtown New Orleans were rejected by the competing local organizations. There also appear to have been lapses in both maintenance and inspections of selected levees, including those that breached. Also, prior to Hurricane Katrina, residents along those same levees reported they were leaking, another potential lapse in maintenance.

Despite the well-known importance of the levees, and the consequences of failure, the local levee boards responsible for maintaining and operating the levees did not have any warning system in place. While federal regulations require that they monitor levees during periods of potential flooding, the requirement is impractical to implement during a hurricane. In addition to no warning system, the loss of communications and

situational awareness, and only sporadic reports of flooding from a variety of sources, made it difficult to confirm that there were breaches in the levees and then to assess the damage. These factors, as well as physical difficulties of getting to the breach sites, combined to delay repair of the levee breaches.

The ultimate causes of the levee breaches, and subsequent flooding of New Orleans, are yet to be determined. At least four forensic investigations are under way to examine scientific evidence and determine the reasons for levee breaches. These include investigations by USACE’s Engineer Research and Development Center, the National Science Foundation (NSF), the American Society of Civil Engineers (ASCE), and Louisiana State University (LSU). Possible causes include (1) the design was not appropriate for the purpose, (2) the storm exceeded levee design standards, (3) the levees were not actually built to the original design standards, (4) the levees were not properly maintained, or (5) a combination of these and other factors.

Finding: Levees protecting New Orleans were not built for the most severe hurricanes

New Orleans is protected from flooding by a system of levees

As noted in the BACKGROUND chapter, hurricanes threaten the Gulf coast every year, and New Orleans is particularly vulnerable because of its location and topography.¹ The majority of the metropolitan area is below sea level. Over the years, the city has continued to sink, due to drainage, subsidence, and compaction of the soils.² As an example of previous damage, Hurricane Betsy brought extensive destruction to New Orleans when it made landfall in Louisiana in September, 1965.³ Unfortunately, many of the descriptions and

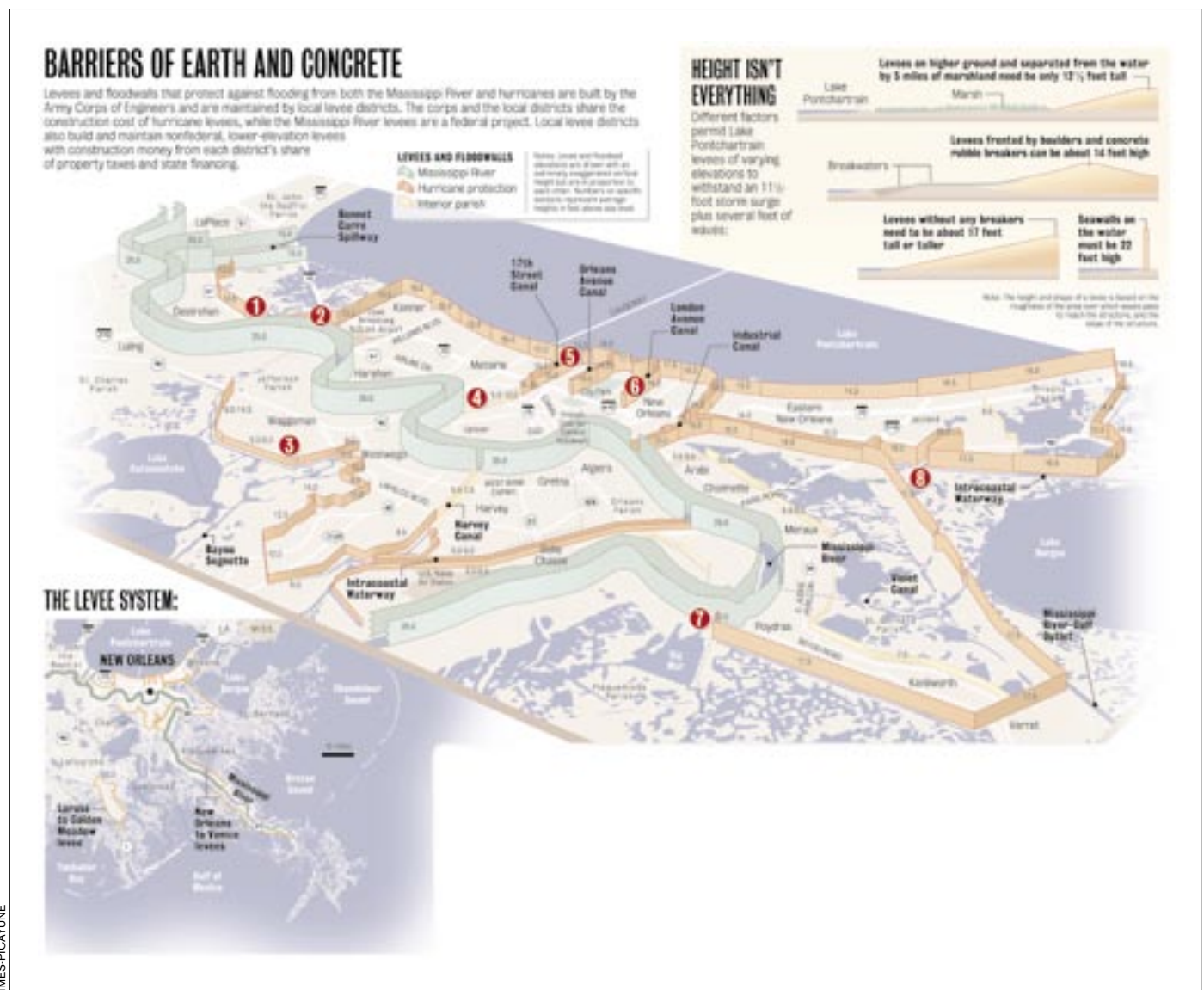


photos from Hurricane Betsy sound and look familiar to our nation as it considers the damage from Hurricane Katrina, forty years later. According to USACE's after action report on Hurricane Betsy...

- She left in her wake a path of devastation unparalleled by any other storm in the recorded history of Louisiana.⁴
- Betsy inundated over 5,000 square miles in Louisiana, including highly populated urban areas in Orleans and St. Bernard Parishes.⁵
- Extensive flooding was caused by overtopping and breaching of existing protection levees in Orleans, Plaquemines, and St. Bernard Parishes.⁶

- As Betsy's winds and tidal surge rolled inland, entire buildings were swept away from their foundations and floated as far as 10 miles away.⁷
- Betsy left 81 dead, over 17,600 injured, and caused the evacuation of 250,000 to storm shelters.⁸
- Betsy left thousands homeless in south Louisiana. Returning refugees often found only a pile of debris where their homes had stood just days before.⁹
- Betsy left numerous towns in south Louisiana with no means of communication.¹⁰

After Hurricane Betsy in 1965, federal and state governments proposed a number of flood control projects to deal with the threat of hurricanes and the flooding they



might cause in New Orleans.¹¹ These included a series of control structures, concrete floodwalls, and levees along Lake Ponchartrain and several other waterways.¹² One of the major projects is formally called the Lake Ponchartrain and Vicinity, Louisiana Hurricane Protection Project.¹³ This project included levees along the Lake Ponchartrain lakefront, the 17th Street Canal, the London Avenue Canal, the Orleans Avenue Canal, the Intercoastal waterway, the Industrial Canal,¹⁴ the Mississippi River Gulf Outlet, and other areas.¹⁵ Although the project was federally authorized, it was a joint federal, state, and local effort with shared costs.¹⁶

Levees were designed for a “standard” hurricane, not the most severe hurricanes

The levees protecting New Orleans were not designed to withstand the most severe hurricanes. According to USACE’s plans for unwatering New Orleans, “the hurricane protection system is not designed for the largest storms and as a result, the metropolitan area is vulnerable to flooding from hurricane storm surges.”¹⁷ USACE originally designed the levees around New Orleans to protect against a hurricane intensity that might occur once every 200-300 years.¹⁸ This protection level was used by USACE, in consultation with the U.S. Weather Bureau,¹⁹ to develop specific criteria for a “standard project hurricane.”²⁰ The “standard project hurricane” is a statistical compilation of many combined hurricane parameters or characteristics intended to simulate a natural hurricane occurrence in southeast Louisiana. The standard project hurricane was used not only for the Lake Ponchartrain project, but also nationwide for all hurricane protection projects where the loss of human life is possible.²¹ According to USACE, the “standard project hurricane” was used to design the New Orleans levees and is roughly equivalent to a fast moving, or “moderate,” category 3 hurricane.²² However, there is no direct comparison of the “standard project hurricane” to a specific category on the Saffir-Simpson Hurricane Scale—which did not exist when the levees were designed.²³ As shown in the table below, the “standard project hurricane” is equivalent to a hurricane with category 2 winds, category 3 storm surge, and category 4 barometric pressure.²⁴

Table 1:
Comparison of “Standard Project Hurricane” with Saffir Simpson Scale

	“Standard project hurricane”	Saffir-Simpson category 2 hurricane	Saffir-Simpson category 3 hurricane	Saffir-Simpson category 4 hurricane
Central pressure (1)	27.6 Hg	28.50-28.91 Hg	27.91-28.47 Hg	27.17-27.88 Hg
Wind speed (2)	100 mph	96-110 mph	111-130 mph	131-155 mph
Radius of maximum winds (3)	30 miles	N/A	N/A	N/A
Average forward speed (3)	6 knots	N/A	N/A	N/A
Storm surge	11.2-13 feet (4)	6-8 feet	9-12 feet	13-18 feet

Source: GAO analysis of USACE and NOAA data.²⁵

Table Notes: The shaded areas indicate those parameters with the closest match between the standard project hurricane and the Saffir-Simpson Scale.

(1) Central pressure is measured in inches of mercury (Hg) or millibars.

(2) Wind speed for the standard project hurricane was measured as the maximum 5-minute average wind speed. The Saffir-Simpson Scale uses the maximum 1-minute average wind speed, a lower threshold.

(3) USACE estimated the radius of maximum winds and the average forward speed for a standard project hurricane, and the Saffir-Simpson Scale does not take either of these parameters into account.

(4) The standard project hurricane calculated maximum surge heights for different geographic areas within the Lake Ponchartrain area. The maximum surge height for the South Shore of Lake Ponchartrain—where the 17th Street, London Avenue, and Industrial Canals are located—was estimated at 11.2 feet.

In addition, there is no “standard” hurricane — the actual forces that levees need to withstand are a function of several factors. According to the preliminary NSF study, “the actual wind, wave and storm surge loadings imposed at any location within the overall flood protection system are a function of location relative to the storm, wind speed and direction, orientation of levees, local bodies of water, channel configurations, offshore contours, vegetative cover, etc. They also vary over time, as the storm moves through the region.”²⁶ Similarly, USACE documents indicate that “[o]vertopping will depend upon the intensity of the storm, the track that the center or “eye” of the storm follows and the speed at which it travels along the track.”²⁷

Although the Lake Ponchartrain project is named a hurricane “protection” project, a number of factors other than saving lives and property are included in the design of such projects. For example, in addition to protecting urban and community lives and health, the design of such projects must include environmental and economic effects, and ensure that benefits of the completed project outweigh its cost of construction.²⁸ In discussing the design of the Lake Ponchartrain project in a 1978 hearing, USACE District Commander for New Orleans, Colonel

Early Rush, stated “Even though economists may, and in this case did, favor protection to a lower scale to produce a higher ratio of benefits to projected costs, the threat of loss of human life mandated using the standard project hurricane.”²⁹

Potential for Katrina to breach levees was well-known, leading to urgent warnings

Even with its hurricane protection system, it was common knowledge that New Orleans was susceptible to hurricane-caused flooding.³⁰ The risks of a major hurricane and flooding in New Orleans had been covered in the general media — by Scientific American (October 2001) and National Geographic (October 2004) — as well as in emergency management literature.³¹ A recent article in the Natural Hazards Observer stated:

When Hurricane Katrina came ashore on August 29, she ended decades of anticipation. There were few hazards in the United States more studied by scientists and engineers and there was ample warning that a strong storm could cause the City of New Orleans to flood.³²

Emergency planners in the local area were particularly knowledgeable about this potentiality. A November 2004 article in Natural Hazards Observer — written by Shirley Laska, of the Center for Hazards Assessment, Response and Technology, at the University of New Orleans — laid out the hypothetical case that Hurricane Ivan had hit New Orleans. The article cites a fictional situation that is now all too real to the nation.³³

New Orleans was spared, this time, but had it not been, Hurricane Ivan would have... caused the levees between the lake and the city to overtop and fill the city “bowl” with water from lake levee to river levee, in some places as deep as 20 feet... Recent evacuation surveys show that two thirds of non-evacuees with the means to evacuate chose not to leave because they felt safe in their homes. Other non-evacuees with means relied on cultural traditions of not leaving or were discouraged by negative experiences with past evacuations. Should this disaster become a reality, it would undoubtedly be one of the greatest disasters, if not *the* greatest,

to hit the United States, with estimated costs exceeding 100 billion dollars. Survivors would have to endure conditions never before experienced in a North American disaster. Hurricane Ivan had the potential to make the unthinkable a reality. Next time New Orleans may not be so fortunate.³⁴

Because of the well-known potential for flooding, USACE has had a plan for several years for draining New Orleans — *Unwatering Plan, Greater Metropolitan Area, New Orleans, Louisiana*, dated August 18, 2000. This plan provides details on the hurricane protection system and describes methods to get the water out after catastrophic flooding from a hurricane. The premise of the plan is that a category 4 or 5 hurricane may produce storm surge water levels of sufficient height to overtop the existing protection system.³⁵ The plan lays out a series of scenarios that could occur, and suggests appropriate emergency responses to unwater the area.³⁶ For example, in one case...

There is catastrophic flooding due to complete overtopping of the levees and floodwalls and inundation of the protected area. There will be extensive and severe erosion of levees and perhaps complete breaches. Due to the high water levels, all of the pumping stations will probably be flooded with major damages The levee districts and drainage departments may be dysfunctional to some degree.³⁷

In more recent years, well before Hurricane Katrina, questions were raised about the ability of the Lake Ponchartrain project to withstand more powerful hurricanes than the “standard project hurricane,” such as a category 4 or 5 hurricane. USACE had discussed undertaking a study of modifications needed to increase the strength of the existing levees, but no formal study was undertaken.³⁸

As discussed earlier in the HURRICANE PAM chapter, FEMA sponsored the “Hurricane Pam” exercise to look at the response to and recovery from a catastrophic hurricane hitting New Orleans and flooding the city. In that scenario, “It was a slow moving Category three storm, something that could quite easily happen, and [the exercise scenario was] designed so that it totally flooded the city, so that the

participants could try to understand the full impacts of a flooded New Orleans” according to Ivor Van Heerden, the LSU professor who used computer modeling to help create a realistic hurricane for the exercise.³⁹ Again, the key reason for that exercise was the well-known potential for levee failure and catastrophic flooding in the metropolitan area.

As Katrina turned and began its track toward New Orleans, the potential for the levees overtopping or breaching and flooding New Orleans resulted in a number of dire warnings from federal, state, and local officials. As also discussed in the EVACUATION chapter, the National Weather Service issued a warning on Sunday, August 28, stating that Katrina was “a most powerful hurricane with unprecedented strength,” that “devastating damage” was expected, that “most of the area will be uninhabitable for weeks,” and that there will be “human suffering incredible by modern standards.”⁴⁰ Governor Blanco also made dire predictions, stating in several interviews on Saturday and Sunday that flooding in New Orleans was a major concern. On Saturday at approximately 8:00 p.m., she appeared on CNN and said that in New Orleans “[t]he storm surge could bring in 15 to 20 feet of water. [People in the city of New Orleans] will not survive that if indeed that happens.”⁴¹ Similarly, in a news conference on Sunday morning, Mayor Nagin said, “The storm surge most likely will topple our levee system.”⁴²

Finding: Responsibilities for levee operations and maintenance were diffuse

USACE oversees design and construction then turns levees over to local sponsors

Several organizations are responsible for building, operating, and maintaining the levees surrounding metropolitan New Orleans. USACE generally contracts to design and build the levees.⁴³ After construction, USACE turns the levees over to a local sponsor.⁴⁴ USACE regulations state that once a local sponsor has accepted a project, USACE may no longer expend federal funds on construction or improvements. This prohibition does not include repair after a flood. Federally authorized flood control projects, such as the Lake Ponchartrain project, are eligible for 100 percent federal rehabilitation if damaged

by a flood.⁴⁵ The Mississippi River levees are the exception to the arrangement just described. USACE operates and maintains these levees. These levees generally withstood Hurricane Katrina, except for a breach south of New Orleans in Plaquemines Parish—the parish that took the full force of Hurricane Katrina at landfall.⁴⁶

The local sponsor has a number of responsibilities. In accepting responsibilities for operations, maintenance, repair, and rehabilitation, the local sponsor signs a contract (called a Cooperation Agreement) agreeing to meet specific standards of performance.⁴⁷ This agreement makes the local sponsor responsible for liability for that levee.⁴⁸ For most of the levees surrounding New Orleans, the Louisiana Department of Transportation and Development was the state entity that originally sponsored the construction. After construction, the state turned over control to local sponsors.⁴⁹ These local sponsors accepted completed units of the project from 1977 to 1987, depending on when the specific units were completed.⁵⁰ The local sponsors are responsible for operation, maintenance, repair, and rehabilitation of the levees when the construction of the project, or a project unit, is complete.⁵¹

Local sponsors do not have control over all factors that could affect their parts of the levee system

The local sponsors include a variety of separate local organizations. For example, different parts of the Lake Ponchartrain and Vicinity, Louisiana Hurricane Protection Project, were turned over to four different local sponsors — to include the Orleans, East Jefferson, Lake Borgne, and Ponchartrain levee districts.⁵² In addition, there are separate water and sewer districts that are responsible for maintaining pumping stations.⁵³ The USACE unwatering plan notes these arrangements by stating that, among other factors, “the political boundaries with internal local levees have resulted in this series of loops or bowls of low lying ground encircled by levees and floodwalls. Each of these areas is served by its own drainage collection and pumping stations.”⁵⁴

The different local organizations involved had the effect of diffusing responsibility and creating potential weaknesses. For example, levee breaches and distress were repeatedly noted at transition sections, where different organizations were responsible for different pieces and

thus two different levee or wall systems joined together. According to USACE, “[a]t sections where infrastructure elements were designed and maintained by multiple authorities, and their multiple protection elements came together, the weakest (or lowest) segment or element controlled the overall performance.”⁵⁵ Similarly, a scientist working on the NFS study, Raymond Seed, stated there needs to be better coordination of these transition sites.⁵⁶ Peter Nicholson, head of an ASCE team investigating the levees, said in response to a question of whether transition sections mattered:

Well, certainly we find that each individual organization will do as they see fit, and when the two sections of the flood control system operated or owned, designed, maintained by each of those different organizations come together, they may be in two different manners. They may have two different heights. They may be two different materials.⁵⁷

The different organizations also have different agendas, and sometimes these can thwart efforts to improve the safety of the overall system. Seed also provided an example where USACE had suggested improvements to the strength of the system that were rejected by the competing organizations. According to Seed:

No one is in charge. You have got multiple agencies, multiple organizations, some of whom aren’t on speaking terms with each other, sharing responsibilities for public safety. The Corps of Engineers had asked to put flood gates into the three canals, which nominally might have mitigated and prevented the three main breaches that did so much destruction downtown. But they weren’t able to do that because, unique to New Orleans, the Reclamation Districts who are responsible for maintaining the levees are separate from the Water and Sewage District, which does the pumping. Ordinarily, the Reclamation District does the dewatering pumping, which is separate from the water system. These guys don’t get along.⁵⁸

While required inspections of levees were done, some deficiencies in maintenance were not fully addressed

Both USACE and the local sponsors have ongoing responsibility to inspect the levees. Annual inspections are done both independently by USACE and jointly with the local sponsor.⁵⁹ In addition, federal regulations require local sponsors to ensure that flood control structures are operating as intended and to continuously patrol the structure to ensure no conditions exist that might endanger it.⁶⁰

Records reflect that both USACE and the local sponsors kept up with their responsibilities to inspect the levees. According to USACE, in June 2005, it conducted an inspection of the levee system jointly with the state and local sponsors.⁶¹ In addition, GAO reviewed USACE’s inspection reports from 2001 to 2004 for all completed project units of the Lake Ponchartrain project. These reports indicated the levees were inspected each year and had received “acceptable” ratings.⁶²

However, both the NSF-funded investigators and USACE officials cited instances where brush and even trees were growing along the 17th Street and London Avenue canals levees, which is not allowed under the established standards for levee protection.⁶³ Thus, although the records reflect that inspections were conducted and the levees received acceptable ratings, the records appear to be incomplete or inaccurate. In other words, they failed to reflect the tree growth, and of course, neither USACE nor the local sponsor had taken corrective actions to remove the trees.

In addition, there was apparently seepage from one canal before Hurricane Katrina, indicating problems had developed in the levee after construction. Specifically, residents of New Orleans who live along the 17th Street Canal said water was leaking from the canal and seeping into their yards months before Hurricane Katrina caused the levee system to collapse. The leaks, they said, occurred within several hundred feet of the levee that later failed.⁶⁴ National Public Radio, which reported the story, said:

State and federal investigators say that a leak may have been an early warning sign that the soil beneath the levee was unstable and help explain why it collapsed. They also say if authorities had investigated and found that a leak was

undermining the levee, they could have shored it up and prevented the catastrophic breach.⁶⁵

National Public Radio also reported that work orders confirm that the Sewerage and Water Board had visited the location of the seepage a number of times. However, both USACE and the Orleans Levee District, with shared responsibilities for inspecting the levees, reported that they had not received any reports of seepage at the site.⁶⁶

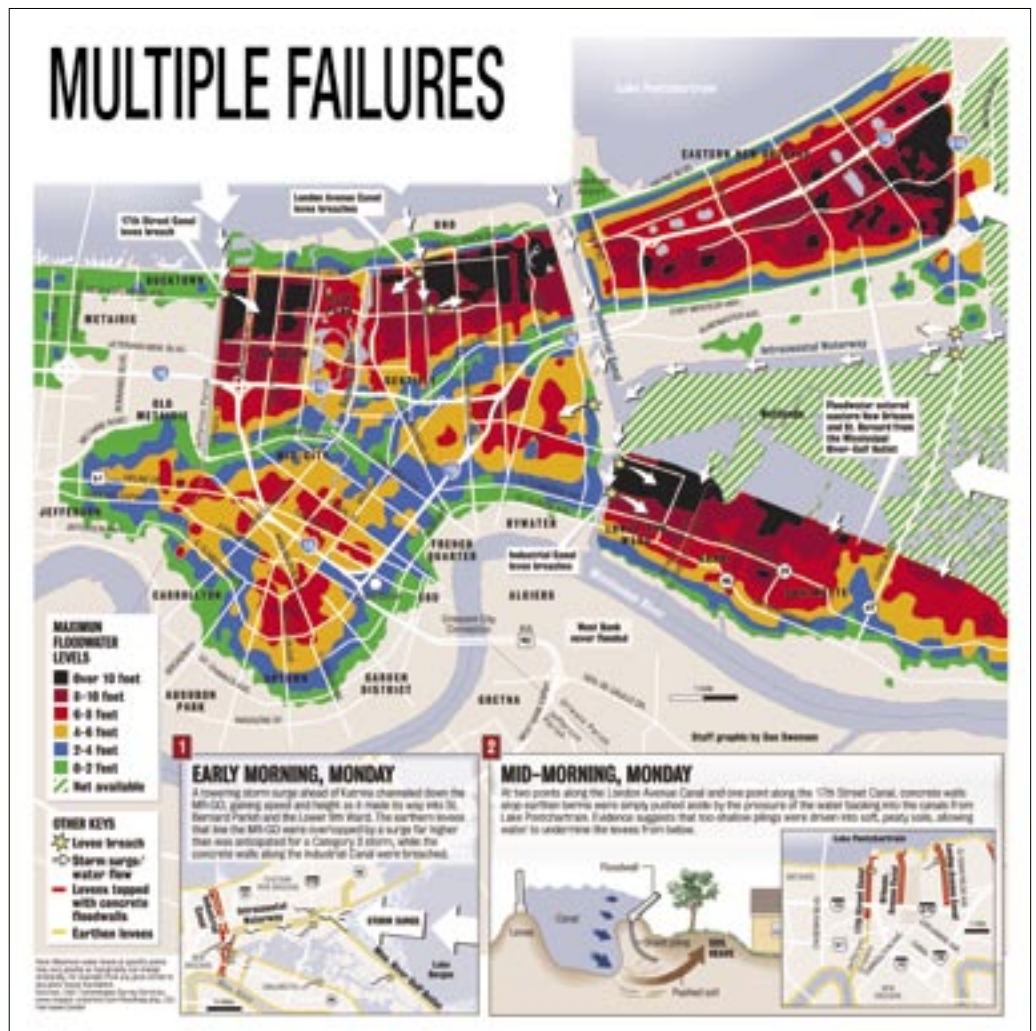
Finding: The lack of a warning system for breaches and other factors delayed repairs to levees

Actual levee breaches caused catastrophic flooding in New Orleans

Katrina made landfall as an “extraordinarily powerful” hurricane.⁶⁷ Katrina was expected to be a category 4 or 5 storm, although a recent updated analysis from the National Weather Service concluded it made landfall at the upper end of a category 3 hurricane (with estimated maximum sustained winds of 110 knots) near Buras, Louisiana.⁶⁸ While Katrina had weakened from its peak intensity of category 5, it remained a very large hurricane — the extent of tropical-force and hurricane-force winds were as large as predicted when Katrina was at maximum intensity.⁶⁹ Due to Katrina’s large size, it is possible that sustained winds of category 4 strength briefly affected the extreme southeastern tip of Louisiana.⁷⁰ However, the sustained winds over all of metropolitan New Orleans and Lake Ponchartrain likely remained weaker than category 3 strength.⁷¹

The storm surge, not the winds, is the most destructive part of a hurricane,⁷² and Katrina produced a massive storm surge. A precise measurement of Katrina’s storm surge in the New Orleans area is difficult to measure, in part because of the widespread failures of tide gauges. However, various efforts are under way to make a definitive determination, particularly near the levees.⁷³ While the surge varied by location, some preliminary estimates are that the storm surge off Lake Borgne, which abuts New Orleans, was approximately 18-25 feet.⁷⁴

One of the highest credible reports of storm surge came from the Hancock County, Mississippi, emergency operations center, where the storm surge was 27 feet.⁷⁵ One reason for the large size of the storm surge was that Katrina, although making landfall as a strong category 3, had already generated large northward propagating swells when it was a category 4 and 5 hurricane during the 24 hours before landfall.⁷⁶ One of the instrument buoys



located south of Dauphin Island, Alabama, measured a wave height of 55 feet — which matches the largest significant wave height ever measured by such a buoy.⁷⁷

Because the eye of Katrina passed just slightly to the east of New Orleans, the hurricane threw unusually severe wind loads and storm surges on the flood protection systems.⁷⁸ The surge overtopped large sections of the levees during the morning of August 29 east of New Orleans, in Orleans and St. Bernard Parish, and it also pushed water up the Intercoastal waterway and into the Industrial Canal. The water rise in Lake Ponchartrain strained the floodwalls along the canals adjacent to its southern shore, including the 17th Street Canal and the London Avenue Canal.⁷⁹ Breaches along all of these canals led to flooding of 80 percent of New Orleans to depths up to 20 feet.⁸⁰ The flooding of central New Orleans led to the most widespread and costly damage of the hurricane. It also led to the difficulties encountered by emergency responders that are documented elsewhere in this report.

The lack of warning systems and degraded communications prevented situational awareness of the breaches in the levees, and delayed repairs

Despite the well-known importance of the levees, and the consequences of failure, the local levee boards responsible for maintaining and operating the levees do not have any warning system in place.⁸¹ Federal regulations require local sponsors to ensure that flood control structures are operating as intended and to continuously patrol the structure *during flood periods* to ensure that no conditions exist that might endanger it.⁸² However, it would be impractical to monitor the levees during a hurricane. The Executive Director of the Orleans Levee District, Max Hearn, stated:

As the hurricane approached, and as water levels began to rise, District employees monitored the water levels and patrolled the flood control system. As weather conditions deteriorated and became unsafe, the District's employees were pulled into sheltered areas to ride out the storm.⁸³

Again, with the large number of local organizations involved, it was not always clear who would be responsible for monitoring the levees and sounding the alarm if there was a breach. According to one scientist,

"If the lines of responsibility and who is in charge aren't clear, it is very hard to decide who needs to be issuing warnings and public notices...."⁸⁴

Given that Hurricane Katrina led to the loss of power and severely degraded communications, as discussed in the COMMUNICATIONS and COMMAND AND CONTROL chapters, it is not clear that any warning system would have survived or have been effective. In the absence of communications that would have provided situational awareness, there were many rumors of flooding and its causes that had to be confirmed before assessment teams and repair teams could be dispatched. There were many sources of these reports of flooding.

- Monday August 29, at 6:00 a.m., floodwaters began flowing into Jackson Barracks, according to Louisiana National Guard officers. Jackson Barracks is near the Orleans Parish – St. Bernard Parish line, and the floodwaters were determined later to be from the Industrial Canal breach. By late Monday morning, the floodwaters were 8-10 feet deep at Jackson Barracks, requiring the Louisiana National Guard to abandon their operations center and re-establish it at the Superdome.⁸⁵
- Monday, August 29, at 7:30 a.m., the state Emergency Operations center (EOC) received reports of flooding in the last conference call before communications were lost. Jefferson Parish relayed unconfirmed reports of significant flooding in the east bank. New Orleans reported extensive flooding in the east and on the lake front. St. Bernard Parish reported "overtopping" of the Industrial Canal and 3 feet of water in Arabi. When the State Coordinating Officer (SCO) Jeff Smith asked if those flooding rumors were confirmed, the parish deputy sheriff said they were confirmed and noted that his building was surrounded by white caps. Smith also stated he was aware of 3-4 feet of floodwaters at Jackson Barracks.⁸⁶
- Monday, August 29, morning (exact time unknown), USACE district commander first heard sporadic reports about levee overtopping and breaches.⁸⁷ The sources of these early reports included local radio stations and a USACE employee reporting overtopping at the Industrial Canal.⁸⁸ Later that day, the USACE district commander issued a situation report, noting flooding

with 4-5 feet of water in Kenner (Jefferson Parish); flooding with 10 feet of water in Arabi (St. Bernard Parish); and water coming into Lakeview (New Orleans) from the 17th Street Canal. The report also said that there was a one-block section of the Industrial Canal that had breached.⁸⁹

- Monday, very late evening (exact time unknown), off duty police officers began calling their police stations from their residences to report flooding near the 17th Street and London Avenue Canals, according to the New Orleans Police Department. Deputy Chief Lonnie Swain said that these reports were the department's first knowledge that flooding was moving into central New Orleans — they had been aware of flooding in East New Orleans (from Lake Ponchartrain) and the Lower Ninth Ward (from the Industrial Canal).⁹⁰

Beyond these reports known to the National Guard, the EOC, and the New Orleans Police Department, USACE was trying to determine the detailed status of the levee system. However, the USACE district commander in New Orleans also suffered from a lack of communications capabilities.⁹¹ As noted earlier, there is no early warning system for levee breaches in New Orleans.⁹² On Monday at about 3:00 p.m., the commander and a team ventured out to conduct early assessments of the situation. They were unable to conduct a thorough review because of the high winds, debris, and flooding. Although they had to return to the bunker, it was clear to them at that point that New Orleans had suffered catastrophic flooding and they began to review plans for unwatering New Orleans.⁹³

On Tuesday, August 30, at about 9:00 a.m., the USACE district commander was able to get a helicopter and see the extent of the flooding from the air.⁹⁴ The USACE district office began to develop more detailed plans for repairing the levees after the airborne reconnaissance on August 30.⁹⁵ USACE has authority to provide a variety of emergency response actions when levees fail or are damaged.⁹⁶ Any repairs to federally constructed levees are funded 100 percent by the federal government.⁹⁷

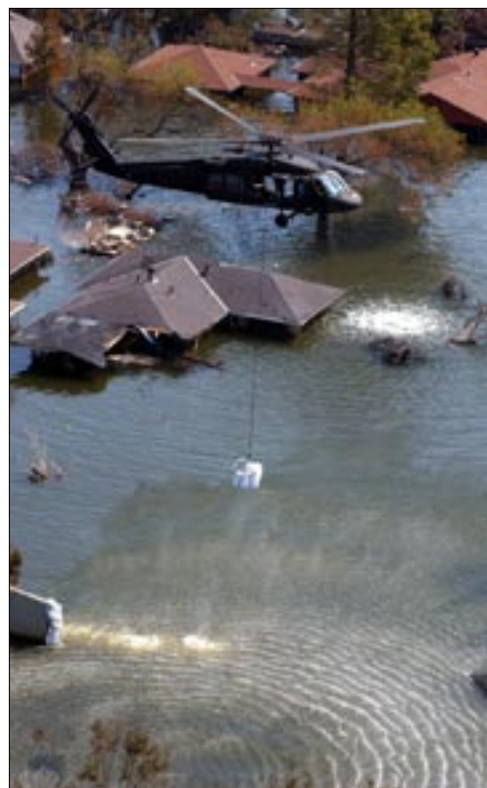
There were also physical barriers that made assessments and repair difficult. Specifically, emergency repair operations to close some of the breaches were seriously hampered by lack of access roads. USACE regulations generally require access roads on top of levees to allow for inspections, maintenance, and flood-fighting operations,

and most USACE levees built in the United States meet this requirement.⁹⁸ However, in New Orleans, exceptions were made to these regulations because of its highly urban nature. Access roads were foregone when it was decided to use I-walls in the levee crowns to minimize right-of-ways into surrounding neighborhoods.⁹⁹ When Hurricane Katrina led to the

breaches in the levees, the lack of access roads atop the levees resulted in very significant increases in time and cost to repair the damaged areas.

Poor communications, difficulties in doing assessments, and physical barriers all served to delay efforts to repair the levees. Levee repairs did not begin until Wednesday, when USACE began marshalling resources — such as contractors, materials, and equipment — at the 17th Street Canal site.¹⁰⁰ The Louisiana National Guard was also involved in these early efforts to conduct emergency repairs of the 17th Street Canal. That afternoon, USACE began dropping 3,000 pound sandbags into the breach.¹⁰¹ The next day contractors started delivering sand, gravel, and rock to the breach site on a newly-built access road. At both the 17th Street Canal and the London Avenue Canal, Army Chinook and Blackhawk helicopters dropped 7,000 pound sandbags—an average of 600 per day—into the breaches. One breach took over 2,000 sandbags before engineers could see the bags under the water surface. According to one witness before the Select Committee, the need for sand was so great that USACE broke into a local business and “took” \$580,000 worth of sand.¹⁰² One week later, the 17th Street Canal breach was closed.¹⁰³

Once the levee repairs were underway, USACE turned its attention to unwatering New Orleans and other flooded areas.¹⁰⁴ Since at least 2000, USACE has had a detailed plan for unwatering greater New Orleans in



the event of flooding. These unwatering plans were also discussed in the “Hurricane Pam” exercise (discussed previously).¹⁰⁵ The exercise assumed the levees did not breach, however there was flooding due to overtopping which inundated New Orleans with at least 10 feet of water. The purpose of the USACE unwatering mission was to remove water from flooded areas (New Orleans), seal off canals from Lake Ponchartrain, repair breaches, create a series of deliberate breaches in the levee system (to help drain them), and pump out final excess with existing and temporary pumps.¹⁰⁶

Through an emergency contracting process, USACE contacted four companies to complete the unwatering activities and, according to USACE, only one company—Shaw Environmental of Baton Rouge—could respond in a timely manner.¹⁰⁷ Projections made prior to Hurricane Katrina that it would take nine weeks to unwater New Orleans proved unfounded.¹⁰⁸ On October 11 (43 days after Katrina landfall) USACE reported that all floodwaters had been removed from the city of New Orleans.¹⁰⁹

Finding: Ultimate cause of levee failures is under investigation, results to be determined

Several investigations are under way to assess causes of levee failure

There are at least four ongoing “forensic” investigations to determine the cause of the levee breaches around New Orleans. These are being done by USACE’s Engineer Research and Development Center; the Center for the Study of Public Health Impacts of Hurricanes, LSU; the National Science Foundation, and ASCE. Each of these investigations has somewhat similar charters and overlapping membership.¹¹⁰

- Interagency Performance Evaluation Task Force (IPET). The USACE Chief Engineer appointed the IPET, headed by the Engineer Research and Development Center, to examine and analyze data in a variety of areas (e.g., Geodetic Reference Datum, Storm and Surge Wave Modeling, Hydrodynamic Forces). At the request of the Secretary of Defense, the results will be analyzed independently by ASCE and the National Research Council.¹¹¹

- Louisiana State University (LSU). The Hurricane Center was appointed by the State of Louisiana to lead the state’s forensic investigation of the Hurricane Katrina levee failures. The investigation team includes engineers and coastal scientists conducting analysis of the storm surge levels, levee construction, and levee failures.¹¹²

- National Science Foundation (NSF). NSF assembled a Levee Investigation Team consisting of leading national and international experts in major disasters.¹¹³ Participating teams of scientists are from the University of California, Berkeley; the Geo-Institute of ASCE; the Coasts, Oceans, Ports and Rivers Institute of ASCE; and the Hurricane Research Center of LSU.¹¹⁴

- American Society of Civil Engineers (ASCE). ASCE assembled an independent team of experts, consisting of professional engineers with a wide range of geotechnical engineering expertise in the study, safety, and inspection of dams and levees. The purpose of the team is to collect data and make observations to determine why certain sections of the levee system failed and others did not.¹¹⁵

Preliminary results suggest some levees did not withstand forces they were designed to withstand

Some of the investigators testified or released reports on their preliminary findings. For example, at a November 2, 2005, Senate Hearing, witnesses included Paul Mlakar, of IPET; Ivor Van Heerden, of LSU; Raymond Seed of the University of California, Berkeley, representing the NSF; and Peter Nicholson of the University of Hawaii, representing the ASCE.¹¹⁶ These witnesses (except Mlakar) testified on the preliminary findings from their investigations. In addition, the NSF and ASCE investigators released a joint interim report, with initial findings, at that hearing.¹¹⁷ A month after the Senate Hearing, IPET released an interim report with a summary of its field observations, which generally concurred with the NSF/ASCE interim report.¹¹⁸ In evaluating the causes of levee and floodwall failure, these preliminary reports indicated the impact of the hurricane, and thus the potential causes of the breaches, varied by location.¹¹⁹

According to preliminary information from NSF, ASCE, and LSU, most of the levees and floodwall breaches on the east side of New Orleans were caused by overtopping,

as the storm surge rose over the tops of the levees and/or their floodwalls and produced erosion that subsequently led to breaches.¹²⁰ A variety of factors led to overtopping of the Industrial Canal and the Mississippi River Gulf Outlet (MR-GO). An LSU Scientist, Hassan Madhriqui, said that MR-GO worked as a funnel which increased the height of the storm surge and “caused floodwaters to stack up several feet higher than elsewhere in the metro area and sharply increased the surge’s speed as it rushed through the MR-GO and into the Industrial Canal.”¹²¹ The overtopping eroded the backside of the canals, scoured out the foundations, and led to their collapse and thus major flooding of adjacent neighborhoods. According to Seed, “A majority of them [levee breaches] were the result of overtopping, and that simply means that the hurricane was bigger than the levees were built to take....”¹²²

In contrast, there was little or no overtopping along most of the levees in the vicinity of Lake Ponchartrain. The only breach along Lake Ponchartrain was in New Orleans East, which was probably due to overtopping. But in the drainage canals that feed into Lake Ponchartrain — the 17th Street and London Avenue Canal — there was no overtopping, and the failures were likely caused by weaknesses in the foundation soil underlying the levees, the weakness in the soils used to construct the earthen levee embankments themselves, or weaknesses caused by vegetation growing along the levees. These were the most costly breaches, leading to widespread flooding of central New Orleans — to include the downtown area and several large residential neighborhoods.¹²³ According to Van Heerden of LSU, “the surge in Lake Ponchartrain wasn’t that of a category 3 storm, and nor did it exceed the design criteria of the standard project hurricane.”¹²⁴ Nicholson of ASCE concurred with this assessment, adding, “If the levees [on Lake Ponchartrain] had done what they were designed to do, a lot of the flooding of New Orleans would not have occurred, and a lot of the suffering that occurred as a result of the flooding would not have occurred.”¹²⁵

However, these findings are preliminary.¹²⁶ Most of the investigations will not issue their final reports until the spring or summer of 2006. For example, the USACE IPET report is scheduled to be completed in June 2006.¹²⁷ Possible causes of the levee breaches include a design not appropriate for the actual application (indicating a shared deficiency), storm conditions simply too overwhelming

for the designed levees to withstand (indicating an act of nature); levee walls not secured deeply enough into the soil or otherwise improperly constructed (indicating a USACE deficiency); improper maintenance of the levees (indicating a local deficiency); or a combination of factors.

Conclusion

Hundreds of miles of levees were constructed to defend metropolitan New Orleans against storm events. These levees were not designed to protect New Orleans from a category 4 or 5 monster hurricane, and all the key players knew this. The original specifications of the

levees offered protection that was limited to withstanding the forces of a moderate hurricane. Once constructed, the levees were turned over to local control, leaving the USACE to make detailed plans to drain New Orleans should it be flooded.

The local sponsors — a patchwork quilt of levee and water and sewer boards — were responsible only for their own piece of levee. It seems no federal, state, or local entity watched over the integrity of the whole system, which might have mitigated to some degree the effects of the hurricane. When Hurricane Katrina came, some of the levees breached — as many had predicted they would — and most of New Orleans flooded to create untold misery.

The forces that destroyed the levees also destroyed the ability to quickly assess damage and make repairs. The reasons for the levee failures appear to be some combination of nature’s wrath (the storm was just too large) and man’s folly (an assumption that the design, construction, and maintenance of the levees would be flawless). While there was no failure to predict the inevitability and consequences of a monster hurricane — Katrina in this case — there was a *failure of initiative* to get beyond design and organizational compromises to improve the level of protection afforded. ■



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- ¹ See Eric S. Blake, et al., Tropical Prediction Center, U.S. Dep't of Commerce, NOAA Technical Memorandum NWS TPC-4, *The Deadliest Costliest, and Most Intense U.S. Tropical Cyclones from 1851 to 2004* (and Other Frequently Requested Hurricane Facts, (Aug. 2005) available at <http://www.nhc.noaa.gov/paststate.shtml> (last visited Jan. 24, 2006); Anu Mittal, U.S. Gov't Accountability Off., Pub. No. GAO-05-1050T, *Testimony Before the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives, Army Corps of Engineers: Lake Pontchartrain and Vicinity Hurricane Protection Project* [hereinafter GAO Hurricane Protection Project], at 2 (Sept. 28, 2005); R.B. Seed, et al., U. of Calif. at Berkely and Am. Soc'y of Civil Engineers, Rept. No. UCB/CITRIS – 05/01, *Preliminary Report on the Performance of the New Orleans Levee System in Hurricane Katrina on August 29, 2005* [hereinafter Report on Levee Performance], at 1-4 (Nov. 2, 2005) (support for subsidence); IEM, Inc., IEM/TEC04-070 r5, *Southeast LA Catastrophic Hurricane Functional Plan* [SE LA Functional Hurricane Plan], at 5 (Jan. 5, 2005).
- ² U.S Army Engineer District, New Orleans, *Un-watering Plan Greater Metropolitan Area, New Orleans, LA* [hereinafter Un-Watering Plan], at 1 (Aug. 18, 2000).
- ³ New Orleans District, U.S. Army Corps of Engineers, *Hurricane Betsy, September 8-11, 1965: After Action Report, 1-5* (July 1966) (Included as App. E in Un-Watering Plan).
- ⁴ *Id.* at 2.
- ⁵ *Id.* at 4.
- ⁶ *Id.* at 32.
- ⁷ *Id.* at 24.
- ⁸ *Id.* at 5.
- ⁹ *Id.* at 29.
- ¹⁰ *Id.* at 26.
- ¹¹ *Hearing on Hurricane Katrina: Who's In Charge of the New Orleans Levees? Before U.S. Senate Committee on Homeland Security and Governmental Affairs* [hereinafter Senate Hearing: Who's in Charge of Levees], 109th Cong. (Dec. 15, 2005) at 2 (written statement of Max. L. Hearn, Executive Director, Orleans Levee District); *Report on Levee Performance*, at 1-3.
- ¹² GAO Hurricane Protection Project, at 2.
- ¹³ Flood Control Act of 1965. Pub. L. No. 89-298, § 204, 79 Stat. 103, 1077 (1965) (The Flood Control Act of 1965 authorized this project).
- ¹⁴ The Industrial Canal is also known as the Inner Harbor Navigation Canal.
- ¹⁵ *Senate Hearing: Who's in Charge of Levees*, at 1-2 (written statement of Col. Richard P. Wagenaar, Commander and District Engineer, New Orleans District, U.S. Army Corps of Engineers); GAO Hurricane Protection Project, at 3.
- ¹⁶ Interview by Select Comm. Staff with David Pezza [hereinafter Pezza Interview], U.S. Army Corps of Engineers (Dec. 9, 2005); GAO Hurricane Protection Project, at 3.
- ¹⁷ Un-Watering Plan, at 1.
- ¹⁸ GAO Hurricane Protection Project, at 4; U.S. Army Corps of Engineers, Release No. PA-05-08, *News Release: U.S. Army Corps of Engineers Hurricane Relief Support and Levee Repair*, (Sept. 3, 2005) (hurricane protection projects were designed to withstand forces of a hurricane that has a 0.5 percent chance of occurrence in any given year).
- ¹⁹ The U.S. Weather Service is now the National Weather Service.
- ²⁰ GAO Hurricane Protection Project, at 4-5.
- ²¹ *Hearing on Hurricane Protection Plan for Lake Pontchartrain and Vicinity Before the House Comm. on Public Works and Transportation Subcommittee on Water Resources* [hereinafter 1978 Hearing on Protection Plan for Lake Pontchartrain], 95th Congress, 45 at 16, (Jan. 5, 1978) (statement of Col. Early Rush, District Engineer, US Army Engineer District, New Orleans) (When USACE designs flood protection projects, it models forces that were expected from the most severe combination of meteorological conditions reasonably characteristic of the region approaching from different paths. This is one of the reasons why, there is a great deal of variability among the heights of the different parts of the flood protection system).
- ²² USACE *News Release: Levee Repair*; GAO Hurricane Protection Project, at 1, 4; Anu K. Mittal, U.S. Gov't Accountability Office, Pub. No. GAO-06-322T, *Testimony Before the Committee on Homeland Security and Governmental Affairs, U.S. Senate: Hurricane Protection: Statutory and Regulatory Framework for Levee Maintenance and Emergency Response for the Lake Pontchartrain Project* [hereinafter GAO Hurricane Protection: Statutory Framework], at 2 (Dec. 15, 2005); Un-Watering Plan, at 3.
- ²³ GAO Hurricane Protection: Statutory Framework, at 4-5.
- ²⁴ *Id.*
- ²⁵ *Id.* at 5.
- ²⁶ *Report on Levee Performance*, at 1-3, 1-4.
- ²⁷ Un-Watering Plan, at 6.
- ²⁸ U.S. Water Resources Council, *Economic and Environmental Principals for Water and Related Land Resources Implementation Studies*, at iv, vi, 12 (Mar. 10, 1983) (These guidelines apply to USACE, among other agencies, and require calculations of impact on (a) national economic development, (b) environmental quality, (c) regional economic impact, and (d) other social effects. The last category includes "urban and community impacts: life, health, safety" and others).
- ²⁹ 1978 Hearing on Protection Plan for Lake Pontchartrain, at 16 (statement of Col. Early Rush).
- ³⁰ See Eric Lipton, *White House Was Told Hurricane Posed Danger*, N.Y. TIMES, Jan. 24, 2006, at A6.
- ³¹ William L. Waugh, Jr., *The Disaster That Was Katrina*, NATURAL HAZARDS OBSERVER, Vol. XXX No. 2, Nov. 2005, at 7-8.
- ³² *Id.*
- ³³ Shirley Laska, *What if Hurricane Ivan Had Not Missed New Orleans?*, NATURAL HAZARDS OBSERVER, Vol. XXIX No. 2, Nov. 2004, at 5-6.
- ³⁴ *Id.*
- ³⁵ Un-Watering Plan, at 1.
- ³⁶ *Id.* at 7.
- ³⁷ *Id.*
- ³⁸ GAO Hurricane Protection Project, at 8.

- ³⁹ Bob Marshall, *Hurricane Pam Exercise Offered Glimpse of Katrina Misery*, TIMES PICAYUNE (New Orleans) Sept. 9, 2005.
- ⁴⁰ National Weather Service, New Orleans, LA, Urgent - *Weather Message, ...Devastating Damage Expected...*, 10:11 AM CDT (Aug. 28, 2005).
- ⁴¹ Interview of Kathleen Babineaux Blanco, Governor of LA, CNN Saturday Night, (Aug. 28, 2005) (8:00 p.m. ET).
- ⁴² Press Conference by C. Ray Nagin, Mayor of New Orleans, and Kathleen Babineaux Blanco, Governor of LA, MSNBC, et al, Aug. 28, 2005.
- ⁴³ Pezza Interview; *Senate Hearing: Who's in Charge of Levees*, at 2 (written statement of Director Hearn); *Report on Levee Performance*, at 6-1; GAO Hurricane Protection Project, at 3.
- ⁴⁴ Pezza Interview; *Senate Hearing: Who's in Charge of Levees*, at 2 (written statement of Director Hearn); *Report on Levee Performance*, at 6-1; GAO Hurricane Protection Project, at 3.
- ⁴⁵ 33 U.S.C. §701t (2005) (They are eligible as long as they are active in USACE's Rehabilitation Inspection Program. To be eligible, they have to pass annual inspections by USACE, which was the case for the Lake Ponchartrain project).
- ⁴⁶ Pezza Interview.
- ⁴⁷ Pezza Interview; *Senate Hearing: Who's in Charge of Levees*, at 3 (written statement of Director Hearn); GAO Hurricane Protection: *Statutory Framework*, at 6.
- ⁴⁸ *Hearing on Hurricane Katrina: Why Did the Levees Fail? Before U.S. Senate Committee on Homeland Security and Governmental Affairs [hereinafter Senate Hearing: Why Did Levees Fail]*, 109th Cong. (Nov. 2, 2005) (statement of Raymond B. Seed, Professor of Civil and Environmental Engineering, University of California, Berkeley).
- ⁴⁹ *Senate Hearing: Who's in Charge of Levees* (written statement of Col. Wagenaar at 2); GAO Hurricane Protection: *Statutory Framework*, at 6.
- ⁵⁰ Pezza Interview; GAO Hurricane Protection: *Statutory Framework*, at 8.
- ⁵¹ Pezza Interview; GAO Hurricane Protection: *Statutory Framework*, at 9.
- ⁵² *Senate Hearing: Who's in Charge of Levees* (written statement of Col. Wagenaar at 2); GAO Hurricane Protection: *Statutory Framework*, at 6.
- ⁵³ *Senate Hearing: Why Did Levees Fail* (statement of R.B. Seed).
- ⁵⁴ *Un-Watering Plan*, at 4.
- ⁵⁵ Interagency Performance Evaluation Task Force, *Interim Report to Task Force Gaurdian, Summary of Field Observations Relevant to Flood Protection in New Orleans [hereinafter Interim Report on Flood Protection in New Orleans]*, LA, at 7 (Dec. 5, 2005).
- ⁵⁶ *Senate Hearing: Why Did Levees Fail* (statement of R.B. Seed).
- ⁵⁷ *Senate Hearing: Why Did Levees Fail* (statement of Peter Nicholson, Associate Professor, Civil and Environmental Engineering, University of Hawaii).
- ⁵⁸ *Senate Hearing: Why Did Levees Fail* (statement of R.B. Seed).
- ⁵⁹ Pezza Interview; *Senate Hearing: Who's in Charge of Levees*, at 3 (written statement of Director Hearn).
- ⁶⁰ Pezza Interview; GAO Hurricane Protection: *Statutory Framework*, at 9.
- ⁶¹ *Senate Hearing: Who's in Charge of Levees*, at 2 (written statement of Col. Wagenaar).
- ⁶² GAO Hurricane Protection: *Statutory Framework*, at 10.
- ⁶³ Pezza Interview; *Report on Levee Performance*, at 2-2.
- ⁶⁴ Frank Langfitt, *Residents Say Levee Leaked Months Before Katrina* National Public Radio, NATIONAL PUBLIC RADIO, MORNING EDITION (Nov. 22, 2005), available at <http://www.npr.org/templates/story/story.php?storyId=5022074> (last visited Feb. 1, 2005).
- ⁶⁵ *Id.*
- ⁶⁶ *Id.*
- ⁶⁷ Richard D. Knabb, et al., National Hurricane Center, Dep't of Commerce, *Tropical Cyclone Report: Hurricane Katrina 23-30 August 2005 [hereinafter NHC: Hurricane Katrina]*, at 1, (Dec. 20, 2005).
- ⁶⁸ *Id.* at 1.
- ⁶⁹ *Id.*
- ⁷⁰ *Id.* at 7.
- ⁷¹ *Id.* at 8.
- ⁷² *Id.* at 11; GAO Hurricane Protection Project, at 2.
- ⁷³ NHC: *Hurricane Katrina*, at 8.
- ⁷⁴ *Report on Levee Performance*, at 1-4.
- ⁷⁵ NHC: *Hurricane Katrina*, at 8.
- ⁷⁶ *Id.* at 9.
- ⁷⁷ *Id.*
- ⁷⁸ *Report on Levee Performance*, at 1-2; NHC: *Hurricane Katrina*, at 9 (Additional support that the surge severely strained the levee system).
- ⁷⁹ NHC: *Hurricane Katrina*, at 9.
- ⁸⁰ *Id.*
- ⁸¹ Pezza Interview.
- ⁸² GAO Hurricane Protection: *Statutory Framework*, at 9.
- ⁸³ *Senate Hearing: Who's in Charge of Levees*, at 4 (written statement of Director Hearn).
- ⁸⁴ *Senate Hearing: Why Did Levees Fail* (statement of R.B. Seed).
- ⁸⁵ Interview by Select Comm. Staff with General Joseph B. Veillon, Assistant Adjutant General for Air, LA Air Nat'l Guard in Baton Rouge, LA (Nov. 3, 2005).
- ⁸⁶ Audio recordings of Hurricane Katrina Conference Calls, LA State Emergency Operations Center (Aug. 26-29, 2005).
- ⁸⁷ *Senate Hearing: Who's in Charge of Levees*, at 4 (written statement of Col. Wagenaar).
- ⁸⁸ *Id.* at 5.
- ⁸⁹ Richard P. Wagenaar, Col., New Orleans District, U.S. Army Corps of Engineers, *Situation report: Event Hurricane Katrina*, (Aug. 29, 2005).
- ⁹⁰ Interview by Select Comm. Staff with Lonnie Swain, Deputy Police Superintendent, New Orleans Police Dep't, in New Orleans, LA, (Nov. 9, 2005).
- ⁹¹ *Senate Hearing: Who's in Charge of Levees* (written statement of Col. Wagenaar).

- ⁹² Pezza Interview.
- ⁹³ *Senate Hearing: Who's in Charge of Levees* (written statement of Col. Wagenaar).
- ⁹⁴ *Id.* at 5.
- ⁹⁵ *Id.* at 6.
- ⁹⁶ Flood Control Act of 1941 § 5, 33 U.S.C. § 701n (2005) (Authorizes USACE to conduct emergency operations and rehabilitation activities when levees fail or are damaged and allows USACE to provide emergency operations to include technical assistance and direct assistance—providing sandbags and pumps, emergency contracting, and levee reinforcement. USACE administrative policies, guidance, and operating procedures for natural disaster preparedness, response, and recovery activities are set out in 33 C.F.R. Part 203 (2005).); *see Senate Hearing: Who's in Charge of Levees*, at 3 (written statement of Col. Wagenaar); also GAO *Hurricane Protection: Statutory Framework*, at 14-15.
- ⁹⁷ GAO *Hurricane Protection: Statutory Framework*, at 10.
- ⁹⁸ U.S. Army Corps of Engineers, Manual No. 1110-2-1913, *Engineering and Design: Design and Construction of Levees*, 8-9 (Apr. 30, 2000).
- ⁹⁹ *See Interim Report on Flood Protection in New Orleans*, at 12-13.
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- ¹⁰¹ *Id.*
- ¹⁰² *Hearing on Hurricane Katrina: Voices from Inside the Storm Before Select Comm.*, 109th Cong., (Dec. 6, 2005) (statement of Harry Alford, President, National Black Chamber of Commerce).
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- ¹⁰⁴ *Id.*
- ¹⁰⁵ *See Un-Watering Plan; SE LA Functional Hurricane Plan*, at 6-7.
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- ¹⁰⁷ *Hearing on Hurricane Katrina: The Federal Government's Use of Contractors to Prepare and Respond Before the Select Comm.*, 109th Cong., (Nov. 2, 2005) (written statement of Norbert Doyle, Col., Principal Assistant Responsible For Contracting (Acting), U.S. Army Corps Of Engineers).
- ¹⁰⁸ Shirley Laska, *What if Hurricane Ivan Had Not Missed New Orleans?*, NATURAL HAZARDS OBSERVER, Vol. XXIX No. 2, Nov. 2004, at 6.
- ¹⁰⁹ NHC: *Hurricane Katrina*, at 9; *see SE LA Functional Hurricane Plan*, at 6.
- ¹¹⁰ *Senate Hearing: Why Did Levees Fail* (statement of Sen. Susan M. Collins, Chairman).
- ¹¹¹ *Senate Hearing: Why Did Levees Fail* (written statement of Paul F. Mlakar, Ph.D., P.E., Senior Research Scientist, U.S. Army Research and Development Center).
- ¹¹² Louisiana State U. Hurricane Center, *Newsbriefs*, <http://hurricane.lsu.edu/newsbriefs.htm> (last visited Jan. 29, 2006).
- ¹¹³ *Senate Hearing: Why Did Levees Fail* (statement of Peter Nicholson).
- ¹¹⁴ *Senate Hearing: Why Did Levees Fail* (statement of R.B. Seed).
- ¹¹⁵ *Report on Levee Performance*, at 1-1.
- ¹¹⁶ *See Senate Hearing: Why Did Levees Fail*.
- ¹¹⁷ *Senate Hearing: Why Did Levees Fail* (statement of Sen. Collins).
- ¹¹⁸ *See Interim Report on Flood Protection in New Orleans*.
- ¹¹⁹ *Report on Levee Performance*, at v; *Senate Hearing: Why Did Levees Fail* (written statement of Paul F. Mlakar).
- ¹²⁰ *Report on Levee Performance*, at iv; *Senate Hearing: Why Did Levees Fail* (statement of Ivor L. van Heerden, Ph.D., Deputy Director, LA State U. Hurricane Center).
- ¹²¹ *Report on Levee Performance*, at 1-5; Matthew Brown, *Katrina may mean MR-GO has to go*, TIMES-PICAYUNE (New Orleans), Oct. 24, 2005, at 1; *Senate Hearing: Why Did Levees Fail* (statement of Ivor L. van Heerden).
- ¹²² *Senate Hearing: Why Did Levees Fail* (statement of R.B. Seed).
- ¹²³ *Report on Levee Performance*, at 1-5; *Senate Hearing: Why Did Levees Fail* (written statement of Paul F. Mlakar) and (statement of Ivor L. van Heerden).
- ¹²⁴ *Senate Hearing: Why Did Levees Fail* (statement of Ivor L. van Heerden).
- ¹²⁵ *Senate Hearing: Why Did Levees Fail* (statement of Peter Nicholson).
- ¹²⁶ *Report on Levee Performance*, at cover, v.
- ¹²⁷ U.S. Army Corps of Engineers, Release No. PA-05-18, *News Release: Interagency Performance Evaluation Task Force – Testing Report on Sheet Pile Foundation Lengths in New Orleans Levees*, (Dec. 9, 2005).

